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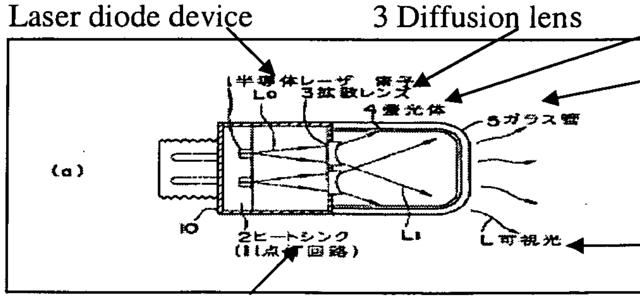
(54) [Title of Invention] Light source equipment for illumination in which a laser diode device is employed.

(57) [Abstract]
[Purpose] To achieve such properties as small energy consumption, excellent endurance, exceeding safety on a light source equipment for illumination, and to enable the equipment to provide the most suitable light such as white light with sufficient output.

[Constitution] The equipment comprises of laser diode device 1 which emits laser light with specific wavelength between infrared rays and ultraviolet rays, a lens 3 which diffuses the laser light emitted from the laser diode device, and a phosphor 4 which converts the laser light diffused by the diffusion lens into a visible light. In addition, this equipment comprises of laser diode devices 1R, 1G, and 1B which emit laser light of three primary colors of red, green, blue, lens 3 which diffuses the laser light emitted by each laser diode device, and lenses 8 and 9 which superimpose the laser lights diffused from these diffusion lenses.

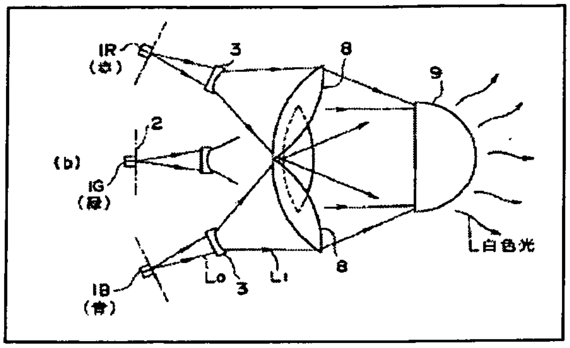
(a)



(b) (red)

(green)

(blue)



White light

[What is claimed is]

[Claim 1] A light source equipment for illumination comprising of a laser diode device which generates laser light with specific wavelength between infrared rays and ultraviolet rays, a lens which diffuses the laser light emitted from the laser diode device, and a phosphor which converts the diffused laser light through the diffusion lens into a visible light.

[Claim 2] The light source equipment for illumination according to Claim 1, wherein the laser diode device is a phased array type in which stripes are divided into multiple stripes with narrow width.

[Claim 3] The light source equipment for illumination according to Claim 1 or 2, wherein a reflection member is installed on a cleaved facet at one side of active layer of laser diode device.

[Claim 4] The light source equipment for illumination according to Claim 1, 2 or 3, wherein mercury atoms or a rare-earth substance is doped to the active layer of laser diode device.

[Claim 5] The light source equipment for illumination according to Claim 1, 2 or 3, wherein second harmonic medium is placed at the output side of laser diode device.

[Claim 6] A light source equipment for illumination comprising; a group of laser diode devices which generate laser light of three primary colors of red, green, blue; a lens which diffuses the laser light from these laser diode devices; and a lend which superimposes the diffused laser lights from the diffusion lens with each other.

[Claim 7] The light source equipment for illumination according to Claim 6, wherein the laser diode device is a phased array type in which stripes are divided into multiple stripes with narrow width.

[Claim 8] The light source equipment for illumination according to Claim 6 or 7, wherein a reflection member is installed on a cleaved facet at one side of active layer of laser diode device.

[Claim 9] The light source equipment for illumination according to Claim 6, 7 or 8, wherein mercury atoms or a rare-earth substance is doped to the active layer of laser diode device.

[Claim 10] The light source equipment for illumination according to Claim 6, 7 or 8, wherein second harmonic medium is placed at the output side of laser diode device.

[Detailed Explanation of Invention]

[0001]

[Field of Industrial Application] The present invention pertains to a light source equipment in which a laser diode is employed which is suitable as a light source to be implemented in such shaky locations as in vehicles or in tunnel, or in locations where it is difficult to exchange light

bulbs, in addition to general illumination equipments including interior light, street light, and flashlights.

[0002]
[Prior Art Technologies] The light sources employed in general illumination equipments include incandescent bulbs wherein a current flows through the filaments in vacuum glass ball filled with argon gas and so on , and visible light is obtained from the heat radiated by the candent filament, and fluorescent lights wherein a glass tube with low pressure of 1Pa (6-10 x 10^{-3} Torr) is filled with mercury vapor with pressure of 100Pa (2-3 Torr), and ultraviolet rays acquired through the collision of thermal electron from electrode filament against mercury atom (wavelength of 253.7nm) are converted into visible light by being emitted to phosphor applied on the internal surface of fluorescent tubes.

[0003] Moreover, light-emitting diode (hereafter described as LED) which is employed in OA equipments and display equipments as a display device is another example. In LED, a current flows through a p-n junction of semiconductors to generate light. As a result of an appropriate selection of the types and compositions of crystallization, LED is commercialized and practically employed in variety of fields including the one where infrared rays are utilized for remote controlling, sensor, and optical communications and the one where visible light is utilized for displaying.

[0004] Regarding visible light LED, there are ones with such light emitting layers as GaA1As (660nm; red), GaAsP (N dope) (590nm: yellow), GaP (555nm: green), SiC (470nm: blue), GaN (450nm: blue). The LEDs with low cost and high luminance have been provided in such colors as red and blue which lagged in development.

[0005]
[Issues that the Invention Intends to Solve] However, incandescent bulbs suffer some problems including the followings. (1) The efficiency of light emitting is unfavorable because almost all of electric current is lost as heat and part of it is radiated as light. (2) The amount of electric consumption is large. (3) Fragile to shake and inferior in endurance (Average life cycle of general illumination bulb is approximately 1000 hours).

[0006] Compared to incandescent bulbs, fluorescent tubes have a superior efficiency of light emitting generating almost no heat. Having said that, there are some problems including (1) Large amount of electric consumption, (2) Inferior endurance (Average life cycle is approximately 10000 hours), (3) Difficulty in achieving small products.

[0007] Furthermore, regarding visible light LED, it has been practically applied in several colors and has such advantages as low cost and small amount of electric consumption. However it has weak output and is difficult to be applied for illumination.

[0008] In addition, as a light source equipment for illumination in which a laser diode is employed, carrying type illumination equipments such as flashlights and searchlights have been proposed. (For example, Laid open utility model application H4-16801). These carrying type illumination equipments employ visible light laser diode as a light source and radiate beam by diffusing the visible light emitted from laser diode through diverging lens. However, because

laser diode generates coherent single color, white light for illumination such as those of white bulbs and fluorescent tubes may not be obtained, and it is a problem that only single color lights such as red and green can be obtained. Moreover the outputs of red and green laser diode are not sufficient at current point, and they can not be applied for illumination without modification.

[0009] The present invention was achieved considering the situations mentioned above. The purpose of the invention is to provide a light source equipment for illumination in which a laser diode is employed with such properties as small amount of electric consumption, excellent endurance, exceeding safety which can generate sufficient amount of preferable light such as white light.

[0010]
[Means to Resolve the Issues] A laser diode device has been applied in such fields as communication, medical care, manufacturing equipments, measurement in civil engineering. The present invention made it possible to apply this device in illumination. In further detail, the invention comprises of a laser diode device which generates laser light with specific wavelength between infrared rays and ultraviolet rays, a lens which diffuses the laser light generated by this laser diode device, and phosphor which converts the diffused laser light from diffusion lens into visible light.

[0011] Moreover, the invention comprises of a group of laser diode devices which generates laser light of three primary colors, red, green, blue, a lens which diffuses the laser light from each laser diode device, and a lens which merges the diffused laser light emitted from diffusion lens.

[0012] Both of AC power and DC power may serve as a power source. When AC power is utilized, a commutation equipment is installed in lighting circuit, and laser diode device and lighting circuit and so on are integrated in single chip.

[0013] The laser diode device is a double hetero junction laser diode. It can have single stripe structure, however, in order to achieve higher output, phased array type in which stripes are divided into smaller stripes is utilized. In addition, such measures as installation of reflection member on the cleave facet at one side of active layer of laser diode device, thickening light guide layer, and employing quantum well structure can be taken.

[0014] Moreover it is also possible to dope mercury atom and rare-earth substance to the active layer of laser diode device so that each color in visible light to ultraviolet regions can be obtained. Furthermore, Second harmonic medium can be installed at the output side of laser diode device to obtain short-wavelength laser light.

[0015]
[Function] In the structure mentioned above, in case of phosphor-type, laser beam with small diameter generated from laser diode device is diffused by lens and emitted onto phosphors, and the light with wavelength between ultraviolet region and infrared region is converted into visible light by the phosphors.

[0016] In case of three-color superimpose type, red, green, and blue laser beams generated by each laser diode device are simultaneously diffused and merged to obtain white light.

[0017] Even in case of laser diode with single stripe structure and relatively small output, a sufficient luminance for illumination is obtainable by installing several of them. If phased array type is applied, it is possible to acquire brighter light with small number of laser diodes.

[0018]
[Embodiment] Hereafter, explanations are made based on examples which describe the present invention. Figure 1 (a) describes an examples of phosphor type light source equipment for illumination in which a laser diode is employed pertaining to the present invention. Figure 1 (B) shows an example of three primary color margining type.

[0019] < phosphor type> In figure 1 (a), multiple laser diode devices 1 are buried or installed in heat sink (heat absorption body) 2. Diffusion lens 3 is installed in front of each laser diode device 1. Phosphors 4 is set on internal surface of vacuum glass tube 5 which is filled with argon gas and so on. Laser beam L_0 generated from laser diode device 1 is diffused by diffusion lens 3, and diffused light L_1 excites fluorescent substance of phosphor 4 to obtain visible light L.

[0020] The structure of laser diode device 1, as described in the following sections, comprises of active layer (light emitting layer) 100, cladding layer 101,102, substrate 103 (Please refer to Figure 5). The crystal structure with the most suitable wavelength for the conversion into visible light conducted by phosphor 4 is selected from the ones whose oscillation wavelength are between infrared range and ultraviolet range.

[0021] Among the crystal structures of laser diode device 1, the one described in Table 1 has been practically employed. However, it is favorable to utilize $A1_xGa_{1-x}As$ in 0.7μm, 0.8 μm region, $In_{1-x}Ga_xAs_vP_{1-v}$ in 1 μm region, and $(A1_xGa_{1-x})In_{0.5}P_{0.5}$ in 0.6 μm region which can continuously oscillate at room temperature in a stable manner with relatively large output.

[0022] Laser diode device 1 in blue to ultraviolet ray regions with short wavelength currently has such problems as a short life cycle of continuous oscillation at room temperature. Therefore it is possible to utilize laser diode device 1 with following structure.

[0023] As described in Figure 2 (a), in this device, mercury Hg is doped by for example, filling the active layer 100 of laser diode device 1 in 0.8 μm region which has relatively large output with mercury vapor when it is generated. Light within active layer 100 is converted into ultraviolet rays by mercury atom Hg generating the laser light with wavelength in ultraviolet region. Moreover, it is possible to generate visible lights of each color and laser light with wavelength in different regions by doping rare-earth substances instead of mercury atom.

[0024] As a method to grow crystal, some new methods, including liquid phase epitaxy in which the crystal to grow is extracted from supersaturated solution or melt, gas phase epitaxy in which raw material is provided in the forms of vapor or gas and accumulated through degradation or synthesis reactions on heated substrate, molecular beam epitaxy, and hot wall epitaxy have been employed. As a method to dope mercury and so on to active layer, it is possible to adapt optical epitaxy in which the vapor generated by shading laser light to gas material is accumulated on substrate.

[0025] In addition, as described in Figure 2 (b), it is possible to obtain the light in blue to ultraviolet regions utilizing laser diode device 1 in 0.8 μm region with relatively large output and SHG (Second Harmonic Generation) device 200 which contains waveguide.

By applying for example, lithium tantalate crystal with polarization reversal layer as SHG device 200, laser light with 870nm of wavelength and 140mW of output can be converted into the blue light with approximately 435nm of wavelength and 10mW of output.

*[0026] The material described in Table 2 is one of the examples for fluorescent substance of phosphor 4. The most suitable fluorescent substance is selected based on oscillation wavelength of the laser diode device 1 to be utilized.

[0027]
*[Table 1]
Double hetero junction laser diode crystal and oscillation wavelength

Group	Active layer	Cladding layer	Substrate	Oscillation wavelength
II-VI	ZnSeS	ZnSeTe	GaP	0.35-0.4 (Ultraviolet-violet)
	ZnSeS	ZnSeTe	GaAs	0.4-0.45(Violet-blue)
	ZnCdSe	ZnSSe	GaAs	0.49-0.53(Blue-blue green)
	ZnSeTe	ZnSeTe	InP	0.5-0.6(Green)
III-V	AlGaInP	AlGaInP	GaAs	0.55-0.4(Yellow-red)
	InGaAsP	AlGaAs	GaAs	0.64-0.9(Red-infrared)
	AlGaAs	AlGaAs	GaAs	0.7-0.9(Infrared)
	InGaAsP	InP	InP	0.9-1.8(Infrared)
	GaInAsSb	GaInAsSb	GaSb	1.8-4.3(Infrared)
IV-VI	PbEuSeTe	PbEuSeTe	PbTe	2.5-6.5(Infrared)
	PbSnSeTe	PbSeTe	PbSnTe	5.5-(Infrared)

[0028] ** [Table 2]
Fluorescent substance and light color

Fluorescent substance	Light color
Calcium tantalate	Blue
Magnesium tantalate	Blue white
Silicate zinc	Green
Halphosphate calsium	White (Daylight color)
Silicate zinc beryllium	Yellow white
Silicate calcium	Yellow red
Cadmium borate	Red

[0029] As described in Figure 3, AC or battery DC power 6 and lighting circuit 7 are connected to laser diode device 1 described above. Current-limit resistance R_1 and luminance adjustment resistance R_2 are imposed in lighting circuit 7 when necessary. When AC power is applied as power 6, rectification diode D is set for a half-wave rectification, or full-wave rectifier D' conducts a full-wave rectification after voltage is lowered to a required level by transformer T. In addition, plurality of laser diode device 1 are installed, and they should be connected with each other in parallel or in the combination of parallel and series connections because lighting failure of one device can fail the lighting of all devices when they are connected in series.

[0030] Regarding diffusion lens 3, when it has single stripe structure as described in the following sections, the shape of the lens is horizontally long oval with beam size of 1x3 μm (AlGaAs: wavelength 0.78 μm) at Near Field Pattern (NFP). The beam expands with divergence angle of approximately 15° (horizontally) and 45° (longitudinal) to generate Far Field Pattern (FFP) of longitudinally long oval shape (Please refer to Figure 5).

The beam diameter is short, and the lens can enlarge a laser beam light with such a short diameter.

[0031] Therefore, diverging lenses are favorable for diffusion lens 3. The lens is made of quarts glass which has high refractive index and small loss of light. The lens is installed with a designated space from laser diode device. Moreover it is possible to improve refraction index by adding lantern which has small loss of light into quartz glass. Furthermore, in production process of the lens, cerium and so on are utilized as an abrasive in grinding the lenses.

[0032] Electric bulbs and fluorescent tubes are the examples of the form of light source equipment for illumination itself. Figure 4 (a) describes the electric bulb type. Heat sink 2 is installed on socket 10, and plurality of laser diode device 1 is installed on heat sink 2. In this case, the size of laser diode device 1 is approximately 4 mm at each side in general, and approximately 12 of the device can be installed in electric bulbs with ordinal size.

[0033] Moreover, lighting circuit 11 which comprises AC-DC converter can be installed in heat sink 2. In this case, optical device and electronic device are integrated in single chip. In addition, plurality of laser diode device 1 can be integrated in single chip. In this case, diffusion lens 3 can be single lens, and plate shape microlens obtained by two-dimensional array (matrixing) of minim lens which corresponds to laser diode device also can serve as diffusion lens 3.

[0034] Furthermore, the laser beam generated by laser diode device 1 with single stripe structure has oval shape and directional property as mentioned above. Therefore, as explained in Figure 4 (b), the directional property is changed by each device 1 in order to make the beam almost omnidirectional. Moreover, phased array, which is explained in the following sections, is also installed with the change of array direction in the same way.

[0035] Figure (C)-(g) describe the examples of fluorescent tube types. (c) and (d) explain double terminal types, and (e) and (f) show single terminal types. Moreover, as described in (g), it is possible to install long heat sink 2 at the one side of glass tube 5, and to place plurality of laser diode device 1 and diffusion lens 3 in the sink with certain space between them.

[0036] <three colors superimpose type> In Figure 1 (b), laser diode device 1R, 1G, 1B are the devices of three primary colors, red, green, blue, respectively. They are buried or installed in heat sink (heat absorption body) 2. Diffusion lens 3 is placed in front of each laser diode device 1, and is overlapped with merger-diffusion lens 9 through collimating lens 8. Laser bema light L_0 which is generated from each laser diode device 1 is diffused by diffusion lens 3 and merged by collimating lens 8 and superimposed to merger-diffusion lens 9 to generate white light. White light L can be radiated in this way.

[0037] Laser diode device 1 is placed, for instance, on single circumference with even space between them. Diffusion lens 3 and collimating lens 8 are installed with their optical axes tilted. In addition, materials for lens 3,8,9 are same as that of phosphor type. Both diverging and converging lenses can function as merger-diffusion lens 9.

[0038] Crystal structure described in aforementioned Table 1 can be employed as that of laser diode device 1R, 1G, 1B. In this case, as the laser diode device 1 of blue with short wavelength, similarly to the case of phosphor type, it is possible to apply the laser diode device 1 with the structure explained as follows.

[0039] In other words, rare-earth substance is doped to the active layer 100 of laser diode device 1 in 0.8 μm region which has relatively large output by filling the layer with vaporized gas of rare-earth substance when it is generated. (Please refer to Figure 2 (a))Through selecting appropriate rare-earth substances, the laser light with wavelength within visible region of each color can be generated.

[0040] Moreover, similarly to the case of phosphor type, it is practical to obtain blue light utilizing laser diode device 1 in 0.8 μm region which has relatively large output and SHG (Second Harmonic Generation) device 200 (Please refer to Figure 2 (b)).

[0041] In addition, the form of equipments and the system of lighting circuits are same as those of phosphor type.

[0042] The structure and principle of laser diode device 1 are explained hereafter. As described in Figure 5, laser diode device generally employs double hetero junction in which active layer (light emitting layer) 100 is sandwiched by cladding layer 101, 102. These structures are formed on metal contact 107 and substrate 104, and contact layer 105, insulation layer 106, and metal contact 107 are formed on cladding layer 101.

[0043] Active layer 100 is the semiconductor with small band gap (Energy gap between valance band and conductor of semiconductors). Cladding layer 101 and 102 are n-type and p-type with lager band gap. When forward voltage is imposed on those layers, electrons and electron holes influx into active layer 100 from n-type region and p-type region respectively.

[0044] These carriers (electrons and electron holes) are confined in active layer 100 due to the energy barrier attributed to band gap in hetero (of different substances) junction. This confinement promotes an efficient reconbination of electrons and electron holes generating spontaneously radiated light. At this stage, like the case of LED, non-coherent light is radiated in all directions.

[0045] Such light which is spontaneously radiated promotes the next recombination of electrons and electron holes triggering induced emission. Edge facet 100a of active layer 100 is the cleaved facet (specific part in crystal grating which is fragile) of crystal, and functions as a reflecting mirror of optical resonator. Therefore induced emission and optical amplification are accelerated while light reciprocates in the optical resonator. In addition, in case of double hetero junction, because the refractive index of active layer 100 is larger than that of cladding layer 101 and 102, active layer 100 functions as a light guide. Therefore light is confined in active layer 100 reducing the loss of light.

[0046] In this case, when imposed current becomes large to certain extent,

laser oscillation can be triggered at certain point, and output of light emitting skyrockets. As a result, the laser light with directionality and narrow spectrum range is shade from both edge facet 100. Compared to LED, the lifecycle of A1GaAs-A1GaAs-GaAs laser is slightly shorter (for instance, 1.3 million hours at 40°C of air temperature, 270 thousand hours at 40°C). However, large light output is obtainable (More than 10mW, 100mW at maximum, to approximately 100mW in practical level).

[0047] By installing plurality of fundamental double hetero junction laser diode device, required output can be obtained. In order to achieve higher output and efficiency, the structure explained below is adapted.

[0048] (1) Phased array type laser diode device is utilized.

[0049] As described in Figure 5, double hetero junction laser diode device in general employs the single stripe structure wherein the region to which electric current is imposed is limited by insulation layer 106 in order to achieve clean oscillation mode and lower threshold current. Widening stripe width can enlarge output. However when the figure exceeds 10 μm, multimode oscillation in filament shape is triggered, making the oscillation uncontrollable, and enlarging oscillation threshold current. Therefore when this single stripe structure is employed, stripe width is enlarged with the limit of 20 μm or more favorably 10 μm.

[0050] Moreover, in order to increase output, as described in Figure 6, phased array type laser diode device (phase-coherent type laser) wherein wide stripes are divided into multiple stripes with narrow width is applied. In this structure, oscillation mode at adjoining each stripe is combined with each other and each phase synchronizes and oscillates as a group to generate a large output. The phase array type has several structures including parallel waveguide type, type to change imposed current, type to change stripe width, diffractive-binding type, offset stripe type, and the output of 10-30W at continuous oscillation is achievable. In practical term, it is favorable to limit the output at 10W considering hear resistance and lifecycle.

[0051] (2) Reflection mirror and reflection film are installed on edge facet of active layer.

[0052] In general, the laser light emitted from cleave facet (reflection facet) at the one side of active layer 100 is utilized for main purpose as a main beam, and the laser light emitted from the other side is utilized for control purpose in order to stable laser output as a monitor beam. As described in Figure 7, reflection mirror 110 is installed at one cleaved facet of active layer 100. The reflection mirror 110 is obtained by the deposition of silver or mercury 110 b on the external surface of quartz glass 110 a.

[0053] When cleaving facet is left as it is, the reflection rate remains around 25%. However, the installation of reflection mirror can drastically improve the figure to, for instance, 90% achieving the substantial reduction of oscillation threshold current and improving light emitting efficiency.

[0054] (3) Thickening optical guide layer.

[0055] As described in Figure 8 (a), thickening optical guide layer 120 can achieve larger output.

[0056] (4) Quantum well structure.
As described in Figure 8 (b), quantum well 130 wherein the thickness of active layer 100 is modified from ordinal figure of 1000-2000 angstrom to 100 angstrom or lower is created. Because the energy situation of electrons can be efficiently converged into specific wave range, high-performance laser with extremely low oscillation threshold current can be obtained. In addition, oscillation wavelength can be changed simply by changing the width of quantum well.

[0057] In addition to the methods mentioned above, surface-emitting laser wherein two-dimensional array can be employed is another option to increase the output of laser diodes and can be adapted when necessary.

[0058] In addition, the applications of the illumination equipment pertaining to the present invention include flashlight, room light, street light, guiding light, courtesy light of automobiles and trains, interior light of vessels, air plane, army vehicles, light in tunnels, light in underground passages, light in harbor tunnel, light in water, stands, decollated chandeliers, and the list goes on.

[0059]
[Advantages of Invention] Because the present invention comprises of the structures described above, it realizes following advantages.

[0060] (1) Energy consumption is small, and the contribution to energy conservation can be made. For instance, the energy consumption of single substance with single stripe structure is 2V of voltage and 20mmA of electric current.

[0061] (2) Life cycle is approximately five times longer than that of mercury lamp, the existing product with longest life cycle. For example, the figure for single substance with single stripe structure is 50-100 thousand hours. The invention is suitable for the application in the locations with difficulty to change bulbs.

[0062] (3) Laser diode device is small, solid, free from disconnection, and excellent in endurance. Therefore it is suitable for the use in shaky locations.

[0063] (4) Because of low voltage, risk of fine is extremely low, and therefore it is safer compared to traditional products.

[0064] (5) Because of the conversion from alternate current to direct current, it is free from flickering and does not exhaust eyes.

[Simple Explanation of Figures]

[Figure 1] Simple cross-section figure which explains light source equipment for illumination pertaining to the present invention. (a) shows phosphor type, and (b) shows three color superimpose type.
[Figure 2] (a) is the simple cross-section figure which describes laser diode device to which mercury and so on are doped. (b) is the simple cross-section figure which shows the example wherein SHG device is installed in laser diode device.

[Figure 3] Circuit pattern which shows the example of power and lighting circuit.

[Figure 4] Simple cross-section figure which describes various forms of the light source equipment for illumination of the present invention.

[Figure 5] Perspective view of the structure of laser diode device with general single stripe structure.

[Figure 6] Perspective view which shows one structure of phased array type laser diode device.

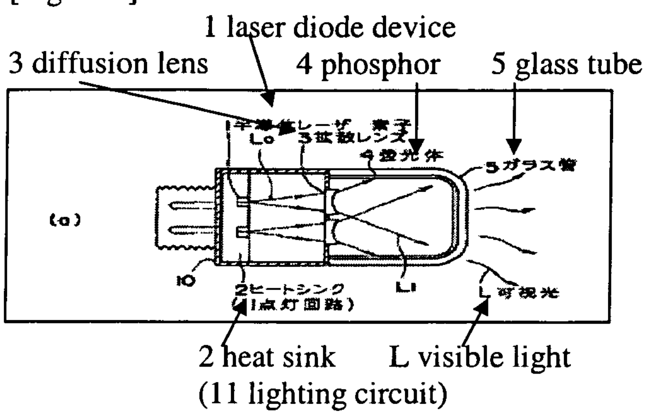
[Figure 7] Cross-section figure which describes the reflection member of active layer of laser diode device.

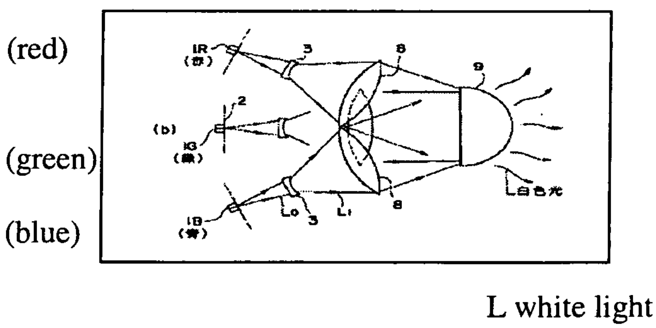
[Figure 8] (a) is the simple elevation view which shows one example of laser diode device in which optical guide layer is created. (b) is the simple elevation view of one example of laser diode device with quantum well structure.

[Explanation of Codes]
*1 laser diode device, 2 heat sink, 3 diffusion lens, 4 phosphor, 5 glass tube, 6 power, 7 lighting circuit, 8 collimating lens, 9 merger-diffusion lens.

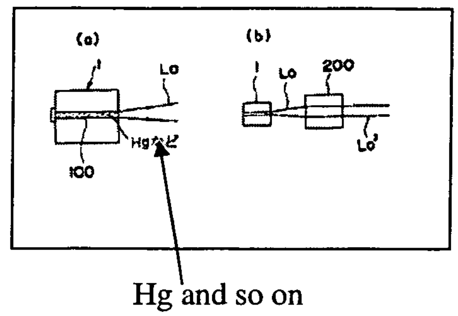
*

[Figure 1]

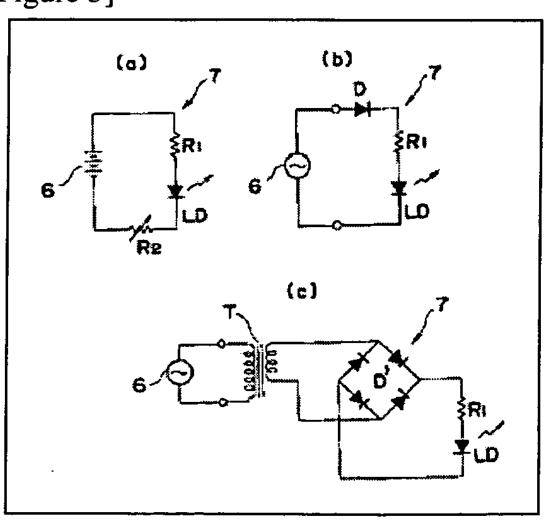




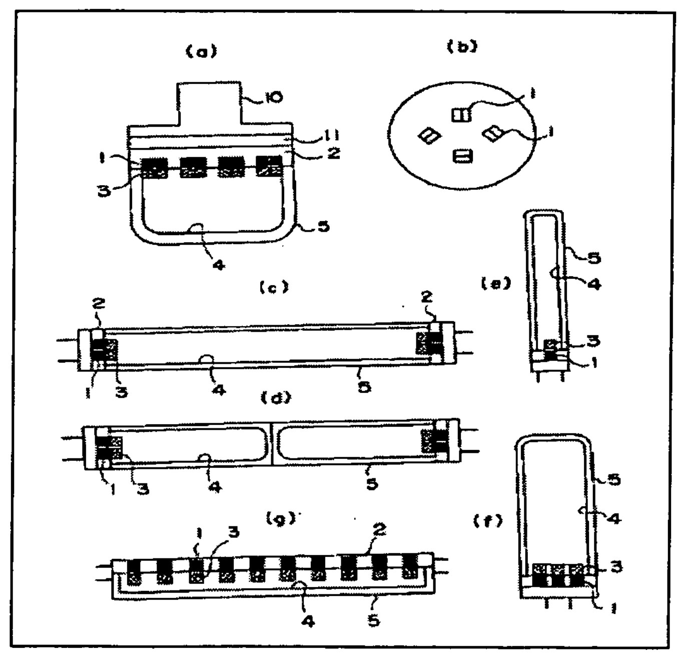
[Figure 2]



[Figure 3]



[Figure 4]



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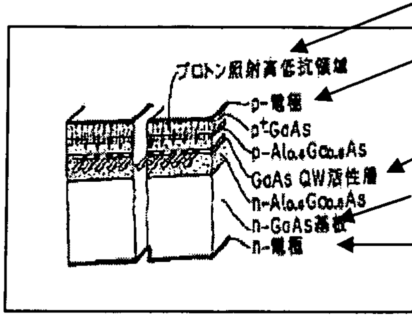
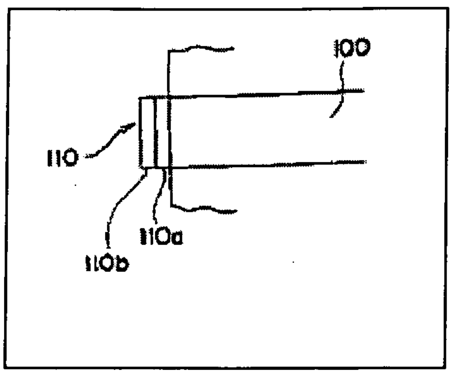
[Figure 6]

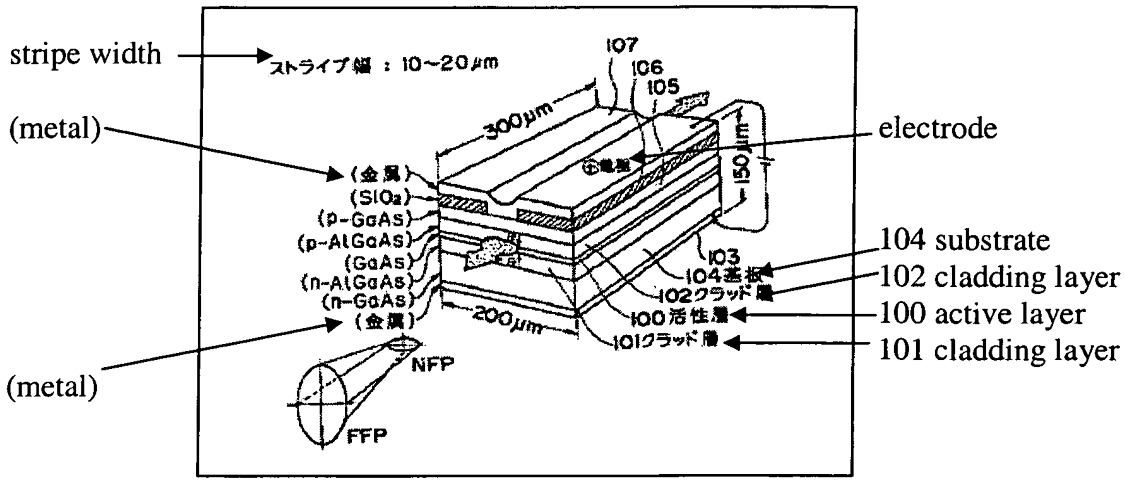


region of high resistance against proton irradiation
p-electrode
GaAs QW active layer
n-GaAs Substrate
n-electrode

[Figure 7]



[Figure 5]



[Figure 8]